An Assessment of Battery and Hydrogen Energy Storage Systems Integrated with Wind Energy Resources in California

Contract #: 500-02-004, UC MR-015
Contractor: University of California, Berkeley
Contract Amount: $74,898
Match Funding: None
Contractor Project Manager: Professor Daniel M. Kammen
Commission Project Manager: Gina Barkalow
Commission Contract Manager: Mike Magaletti

The Issue

California's renewable portfolio standard (RPS) requires the state's electricity generating companies to produce or purchase 20% of the electricity they sell from renewable technologies by 2017.[1] In 2004, the Energy Commission took that vision a step further and recommended that the 20% goal be met by 2010 and that a further goal of 33% renewables by 2020 be pursued.[2]

Stuart Energy Systems Electrolyzer/Hydrogen Generator Being Coupled to a Wind Turbine Array in Palm Desert, California (May, 2003)

Technologies such as wind turbines and photovoltaics (PV) are poised to contribute substantially in meeting this goal; however, their widespread use is hindered by their inability to provide steady power when the wind is not blowing or the sun is not shining. Power contract rules typically penalize these "intermittent" renewables for failing to provide power when predicted, and often fail to compensate them fully for production in excess of predictions.

To help these intermittent renewable technologies become more competitive with fossil and hydroelectric power plants, their electricity can be stored so that they can be dispatched at any time. Energy storage can also ease the integration of wind turbines with the utility grid, and can provide spinning reserve and other ancillary grid services. However, energy storage entails varying economic costs and environmental impacts depending on the storage technology used.

1. SB 1078, Sher, Chapter 516, Statutes of 2002.

2. California Energy Commission. November 2004. *Integrated Energy Policy Report, 2004 Update*. 100-04-006CM.

Project Description

PIER-EA's Exploratory Grant Program funded the University of California, Berkeley, to assess energy storage systems offering the potential to improve wind turbine economics. The project focused on four energy storage options: lead acid (solid-state) batteries; zinc bromine (flow) batteries; a hydrogen electrolyzer/fuel cell system; and a hydrogen electrolyzer/fuel cell connected to a hydrogen refueling station, whereby the stored hydrogen would be sold as a fuel for hydrogen-powered vehicles rather than reconverted back into electricity.

These technologies were assessed in the context of four California wind farm sites that are likely to experience significant development in the coming years: Altamont Pass and Solano in Northern California, and Tehachapi and San Gorgonio in Southern California.

Two wind penetration scenarios were considered: 10% the year 2010 (1% in Northern California and 9% in Southern California); and 20% in 2020 (2% in Northern California and 18% in Southern California).

Analysis was conducted using the HOMER model developed by the National Renewable Energy Laboratory. HOMER was modified to include hour-by-hour characterizations of wind at the four sites as well as the projected technical and economic performance of the energy storage options for the two time frames. The study also accounted for the north-south transmission constraints imposed by Path 15.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing environmentally sound electricity.** Energy storage systems can improve the economics of wind power by making it more "dispatchable" and mitigating some of the technical issues associated with wind turbine integration into the utility grid. This economic scoping study is a step toward understanding the overall value proposition for energy storage as a means to promote further deployment of wind power (and potentially other intermittent renewable resources as well).
- **Providing reliable electricity.** Integrating energy storage with wind turbines can help to maintain grid stability and adequate reserve margins, thereby contributing to the overall reliability of the electricity grid.
- **Providing affordable electricity.** Diversification of electricity supplies with relatively low-cost sources such as wind power can provide a hedge against natural gas price increases.

Results

Utilization of energy storage was determined by the availability of "excess" off-peak electricity from wind power. The energy storage systems were not particularly well utilized in the 2010 scenario (10% wind penetration). Storage systems were better utilized—up to 1600 hours per year—in the 2020 scenario (20% wind penetration). The low utilization levels modeled for 2010 were due partly to the assumptions used in this analysis (e.g., that energy storage is used for bulk power storage from wind during time-averaged 15-minute periods of high availability and not to absorb energy over shorter time periods to address the wind availability forecasting error issue). More generally, the low energy storage utilization for 2010 resulted from the lack of significant *excess* wind power availability, particularly with the relatively low wind penetration levels assumed for the Northern California sites (~1% of statewide energy use).

In the 2010 scenarios, the flow (zinc bromine) battery system delivered the lowest cost per energy stored and delivered. As wind penetration increased, the hydrogen options became the most economical, and sale of hydrogen as a vehicle fuel was more lucrative than reconverting the hydrogen back into electricity.

Levelized costs of energy storage ranged from a low of $0.41/kWh—or near the marginal cost of generation during peak demand periods—to many dollars per kWh (when storage was not well utilized). It may thus be necessary to optimize storage system output to coincide with peak demand periods, and to identify value streams from the additional benefits that storage systems provide (power quality, grid ancillary services, etc.).

In general, energy storage systems are environmentally benign, except for emissions from the manufacture of certain battery components.

The research team concluded that energy storage systems can potentially improve the technical and economic attractiveness of wind power in California, particularly when wind power exceeds about 10% of total system energy (about 20%–25% of system capacity). The overall value proposition for energy storage integrated with renewables depends on diverse factors:

- The interaction of generation and storage system characteristics and grid and energy resource conditions at a particular location
- The use of energy storage for multiple purposes in addition to improved dependability/ dispatchability (e.g., peak/off-peak power price arbitrage, helping to optimize the transmission and distribution infrastructure, load-leveling the grid in general, mitigating power quality issues)
- Future progress in improving forecasting techniques and reducing prediction errors for intermittent renewable energy systems
- Electricity market design and rules for compensating renewable energy systems for their output

The research team anticipates only limited application of energy storage systems in conjunction with renewable energy development in California for at least the next several years. However, application of energy storage technologies may become more attractive in the future with higher levels of wind power use, depending on the outcome of efforts to better integrate intermittent renewable energy systems into utility grids and on the evolution of energy storage system cost and performance.

Final Report

The final report for this project will be available in August 2005 and will be posted at http://www.energy.ca.gov/pier/final_project_reports/CEC-500-2005-136.html.

Contact

Gina Barkalow • 916-654-4057 • Gbarkalow@energy.state.ca.us